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|  | **Unit 1: Biochemistry** | | | | | | | | | | | |
| Name: | | Start Date: | | | | | 08/30/16 |  | |  | |  |
|  | | Test 1 Date: | | | | | **09/19/16** |  | |  | |  |
| Period: (Honors) | | Teacher: Ms. Jost | | | | | |  | |  | |  |
|  | |  |  | |  |  | |  | |  | |  |
| **BIOCHEMISTRY** | | Submitted | Resubmit | | Correct | Evidence of Learning | | Page # | | Date | | Sign-Off |
| **Objective 2:** Explain how enzymes act as catalysts for biological reactions | |  |  |  | | **Enzymes Video Questions**  **Origins of Lactose Intolerance**  **Activity: Lactose Intolerance** | | | 3 | |  |  |
|  |  |  | | 4 | |  |  |
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|  |  |  | | **Catalyst: Latin Roots**  **Notes: Enzymes** | | | 9 | |  |  |
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|  |  |  | | **Lab: Lactase Enzyme** | | | 12 | |  |  |
|  |  |  | | **Catalyst: Enzymes**  WebQuest: Enzymes  POGIL: Enzymes & Cellular Regulation | | | 17 | |  |  |
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**Unit 1: BioChemistry**

Start Date: 08/30/16

Test 1 Date: 09/19/2016

**Objective 1:** Compare the structures and functions of the major biological molecules (carbohydrates, proteins, lipids, and nucleic acids) as related to the survival of organisms.

*Essential Question:* What are the subunits and functions of the four major groups of organic molecules?

*“I Can” Statements:*

* Compare and contrast the four major organic macromolecule groups in terms of:
  + The formative elements
  + The formative subunits (monomers)
  + Functions within the cell/organism
  + Where found in the diet (food sources)

**Objective 2:**  Explain how enzymes act as catalysts for biological reactions.

*Essential Question:* How and why do enzymes catalyze biological reactions?

*“I Can” Statements:*

* Demonstrate the link between shape and function as it relates to an enzyme-substrate complex, as well as the effects of environmental factors (temperature, pH) on enzyme efficiency
* Develop a cause-and-effect model for specificity of enzymes

**Vocabulary**

* Activation Energy
* Amino Acid
* Carbohydrate
* Catalyst
* Denature
* DNA
* Enzyme
* Fatty Acid
* Hormone
* Lipid
* Macromolecule
* Monomer
* Monosaccharide
* Nucleic Acid
* Nucleotide
* Organic
* Peptide Bond
* Polymer
* Polysaccharide
* Product
* Protein
* Reactant
* RNA
* Substrate

**Introduction to Enzymes**

Video response questions:

1.What is an enzyme?

2. What does it mean to catalyze a reaction?

3. Where are digestive enzymes produced?

4. Where does digestion usually begin?

5. Proteins are primarily digested in the \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.

6. How do the enzymes “digest” or break down the biomolecules?

7. How are nutrients distributed throughout the body?

8. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ foods are rich in digestive enzymes.

9. How does ageing affect enzyme production?

Video: https://www.youtube.com/watch?v=AFbPHlhI13g

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| |  |  | | --- | --- | | Source: | [Cornell University](http://www.cornell.edu" \t "_blank) | | Date: | June 2, 2005 | |  |  |

# Lactose Intolerance Linked To Ancestral Environment

ITHACA, N.Y. -- Got milk? Many people couldn't care less because they can’t digest it. A new Cornell University study finds that it is primarily people whose ancestors came from places where dairy herds could be raised safely and economically, such as in Europe, who have developed the ability to digest milk.

On the other hand, most adults whose ancestors lived in very hot or very cold climates that couldn’t support dairy herding or in places where deadly diseases of cattle were present before 1900, such as in Africa and many parts of Asia, do not have the ability to digest milk after infancy.

“The implication is that harsh climates and dangerous diseases negatively impact dairy herding and geographically restrict the availability of milk, and that humans have physiologically adapted to that,” said evolutionary biologist Paul Sherman, a professor of neurobiology and behavior at Cornell. “This is a spectacular case of how cultural evolution -- in this case, the domestication of cattle -- has guided our biological evolution.”

Although all mammalian infants drink their mothers’ milk, humans are the only mammals that drink milk as adults. But most people -- about 60 percent and primarily those of Asian and African descent -- stop producing lactase, the enzyme required to digest milk, as they mature. People of northern European descent, however, tend to retain the ability to produce the enzyme and drink milk throughout life.

Sherman and former Cornell undergraduate student Gabrielle Bloom '03, now a graduate student at the University of Chicago, compiled data on lactose intolerance (the inability to digest dairy products) from 270 indigenous African and Eurasian populations in 39 countries, from southern Africa to northern Greenland. Their findings will be published in a forthcoming issue of Evolution and Human Behavior.

On average, Sherman and Bloom found that 61 percent of people studied were lactose intolerant, with a range of 2 percent in Denmark and 100 percent in Zambia. They also found that lactose intolerance decreases with increasing latitude and increases with rising temperature, and especially with the difficulty in maintaining dairy herds safely and economically.

A major challenge in interpreting the data, Sherman noted, was to resolve the puzzle that about 13 lactose-tolerant populations live side-by-side with lactose-intolerant populations in some parts of Africa and the Middle East.

“The most likely explanation is nomadism,” Sherman concluded. All 13 of the populations that can digest dairy yet live in areas that are primarily lactose intolerant were historically migratory groups that moved seasonally,” Sherman said. “Their nomadism enabled them to find suitable forage for their cattle and to avoid extreme temperatures. Also, the fact that these groups maintained small herds and kept them moving probably reduced the pathogen transmission rate.”

According to the National Digestive Diseases Information Clearinghouse, some 30 million to 50 million Americans are lactose intolerant, including up to 75 percent of African Americans and American Indians and 90 percent of Asian Americans. Common symptoms include nausea, cramps, bloating, gas and diarrhea that begin about 30 minutes to two hours after eating or drinking foods containing the milk sugar lactose. The use of lactase enzyme tablets or drops or lactose-reduced milk and similar products can help the lactose intolerant digest dairy products.

Sherman’s study concludes that adults from Europe can drink milk because their ancestors lived where dairying flourished and passed on gene mutations that maintain lactase into adulthood. The research, he said, is an example of Darwinian medicine, a new interdisciplinary field of science that takes an evolutionary look at health, and considers why, rather than how, certain conditions or symptoms develop.

**YOUTUBE VIDEO:** [**https://www.youtube.com/watch?v=MA9boI1qTuk**](https://www.youtube.com/watch?v=MA9boI1qTuk)

1. What groups of people are typically able to digest milk products?
2. What percentage of humans is unable to digest milk products after childhood?
3. What is lactose intolerance?
4. What groups of people are typically NOT able to digest milk after childhood?
5. What enzyme is responsible for digestion of lactose?
6. Why is it thought that Europeans developed the gene for the enzyme that allows them to digest milk?

## Lactose Intolerance

## What is lactose?

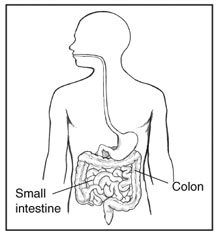
Lactose is a sugar found in milk and milk products. The small intestine—the organ where most food digestion and nutrient absorption take place—produces an enzyme called lactase. Lactase breaks down lactose into two simpler forms of sugar: glucose and galactose. The body then absorbs these simpler sugars into the bloodstream.

## What is lactose intolerance?

Lactose intolerance is a condition in which people have digestive symptoms—such as bloating, diarrhea, and gas—after eating or drinking milk or milk products.

Lactase deficiency and lactose malabsorption may lead to lactose intolerance:

* **Lactase deficiency.** In people who have a lactase deficiency, the small intestine produces low levels of lactase and cannot digest much lactose.
* **Lactose malabsorption.** Lactase deficiency may cause lactose malabsorption. In lactose malabsorption, undigested lactose passes to the colon. The colon, part of the large intestine, absorbs water from stool and changes it from a liquid to a solid form. In the colon, bacteria break down undigested lactose and create fluid and gas. Not all people with lactase deficiency and lactose malabsorption have digestive symptoms.

  
The digestive tract

People have lactose intolerance when lactase deficiency and lactose malabsorption cause digestive symptoms. Most people with lactose intolerance can eat or drink some amount of lactose without having digestive symptoms. Individuals vary in the amount of lactose they can tolerate.

People sometimes confuse lactose intolerance with a milk allergy. While lactose intolerance is a digestive system disorder, a milk allergy is a reaction by the body’s immune system to one or more milk proteins. An allergic reaction to milk can be life threatening even if the person eats or drinks only a small amount of milk or milk product. A milk allergy most commonly occurs in the first year of life, while lactose intolerance occurs more often during adolescence or adulthood.[1](https://www.niddk.nih.gov/health-information/health-topics/digestive-diseases/lactose-intolerance/Pages/facts.aspx#sup1),[2](https://www.niddk.nih.gov/health-information/health-topics/digestive-diseases/lactose-intolerance/Pages/facts.aspx#sup2)

1Boyce JA, Assa’ad A, Burks AW, et al. Guidelines for the diagnosis and management of food allergy in the United States: report of the NIAID-sponsored expert panel. Journal of Allergy and Clinical Immunology. 2010;126(6 suppl.):S1–S58.

2Suchy FJ, Brannon PM, Carpenter TO, et al. National Institutes of Health Consensus Development Conference: lactose intolerance and health.Annals of Internal Medicine. 2010;152(12):792–796.

## Who is more likely to have lactose intolerance?

In the United States, some ethnic and racial populations are more likely to have lactose intolerance than others, including African Americans, Hispanics/Latinos, American Indians, and Asian Americans. The condition is least common among Americans of European descent.[2](https://www.niddk.nih.gov/health-information/health-topics/digestive-diseases/lactose-intolerance/Pages/facts.aspx#sup2)

## What are the symptoms of lactose intolerance?

Common symptoms of lactose intolerance include

* abdominal bloating, a feeling of fullness or swelling in the abdomen
* abdominal pain
* diarrhea
* gas
* nausea

Symptoms occur 30 minutes to 2 hours after consuming milk or milk products. Symptoms range from mild to severe based on the amount of lactose the person ate or drank and the amount a person can tolerate.

## How does lactose intolerance affect health?

In addition to causing unpleasant symptoms, lactose intolerance may affect people’s health if it keeps them from consuming enough essential nutrients, such as calcium and vitamin D. People with lactose intolerance may not get enough calcium if they do not eat calcium-rich foods or do not take a dietary supplement that contains calcium. Milk and milk products are major sources of calcium and other nutrients in the diet. Calcium is essential at all ages for the growth and maintenance of bones. A shortage of calcium intake in children and adults may lead to bones that are less dense and can easily fracture later in life, a condition called osteoporosis.

## How is lactose intolerance managed?

Many people can manage the symptoms of lactose intolerance by changing their diet. Some people may only need to limit the amount of lactose they eat or drink. Others may need to avoid lactose altogether. Using lactase products can help some people manage their symptoms.

For people with secondary lactase deficiency, treating the underlying cause improves lactose tolerance. In infants with developmental lactase deficiency, the ability to digest lactose improves as the infants mature. People with primary and congenital lactase deficiency cannot change their body’s ability to produce lactase.

## Eating, Diet, and Nutrition

People may find it helpful to talk with a health care provider or a registered dietitian about a dietary plan. A dietary plan can help people manage the symptoms of lactose intolerance and make sure they get enough nutrients. Parents, caretakers, childcare providers, and others who serve food to children with lactose intolerance should follow the dietary plan recommended by the child’s health care provider or registered dietitian.

**Milk and milk products.** Gradually introducing small amounts of milk or milk products may help some people adapt to them with fewer symptoms. Often, people can better tolerate milk or milk products by having them with meals, such as having milk with cereal or having cheese with crackers. People with lactose intolerance are generally more likely to tolerate hard cheeses, such as cheddar or Swiss, than a glass of milk. A 1.5‑ounce serving of low-fat hard cheese has less than 1 gram of lactose, while a 1-cup serving of low-fat milk has about 11 to 13 grams of lactose.[2](https://www.niddk.nih.gov/health-information/health-topics/digestive-diseases/lactose-intolerance/Pages/facts.aspx#sup2)

However, people with lactose intolerance are also more likely to tolerate yogurt than milk, even though yogurt and milk have similar amounts of lactose.[2](https://www.niddk.nih.gov/health-information/health-topics/digestive-diseases/lactose-intolerance/Pages/facts.aspx#sup2)

**Lactose-free and lactose-reduced milk and milk products.** Lactose-free and lactose-reduced milk and milk products are available at most supermarkets and are identical nutritionally to regular milk and milk products. Manufacturers treat lactose-free milk with the lactase enzyme. This enzyme breaks down the lactose in the milk. Lactose-free milk remains fresh for about the same length of time or, if it is ultra-pasteurized, longer than regular milk. Lactose-free milk may have a slightly sweeter taste than regular milk.

**Lactase products.** People can use lactase tablets and drops when they eat or drink milk products. The lactase enzyme digests the lactose in the food and therefore reduces the chances of developing digestive symptoms. People should check with a health care provider before using these products because some groups, such as young children and pregnant and breastfeeding women, may not be able to use them.

Source: “Lactose Intolerance.” *U.S National Library of Medicine*, U.S. National Library of Medicine, https://www.niddk.nih.gov/health-information/health-topics/digestive-diseases/lactose-intolerance/pages/facts.aspx.

**Response Questions**

1. What is the difference between lact**ose** and lact**ase**?

2. What does it mean to be lactose intolerant?

3. How can lactose intolerance affect someone’s health? What major nutrient is found in milk?

4. Name three ways people who are lactose intolerant might change their diet to manage their condition:

1.

2.

3.

**Catalyst: Latin Roots**

Using the Latin roots packet you received last week, work with the people around you to define the following terms:

**Mono/mer-**

**Poly/sacchar/ide-**

**Cata/lyst**-

**Re/act/ion-**

**De/nat/ure-**

Biology I (Honors) Name: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Notes: Enzymes Period: \_\_\_\_ Date: \_\_\_/\_\_\_/\_\_\_

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Biology I Name: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Enzyme Lab Period: \_\_\_\_ Date: \_\_\_/\_\_\_/\_\_\_

**Objective 2:**  Explain how enzymes act as catalysts for biological reactions.



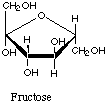
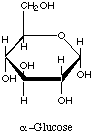
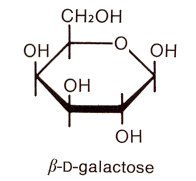
**Introduction:**

What is the topic of this ad? Who would use such a product? Why would they need it?

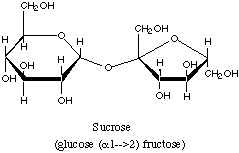
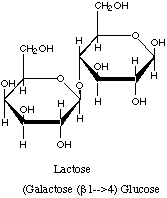
According to statistics, approximately one-third of all Americans feel ill after consuming milk and other dairy products. We were taught that we should “drink our milk” by our parents. “It is good for you, will help you have strong bones and teeth, and grow healthy and tall.” The nutritional value of milk is a fact. However, most animals stop drinking milk after they are weaned and their body chemistry changes so that they can no longer digest the sugar in milk. Worldwide this is also true of the human population. That is what is normal. It is actually unusual for adults to be able to digest milk easily.

In this lab activity, you will learn more about lactose intolerance. You will understand the chemical structure of lactose, why a person may have difficulty digesting milk, how lactose tolerance may have started, why so many Americans can digest it, and how lactose-reduced products can help people.

Lactose, the sugar found in milk, is a disaccharide composed of glucose and galactose (both six-sided sugars). Sucrose, ordinary table sugar, is also a disaccharide composed of fructose and glucose. Glucose is a six-sided sugar and fructose is a five-sided sugar.

Fructose Glucose Galactose

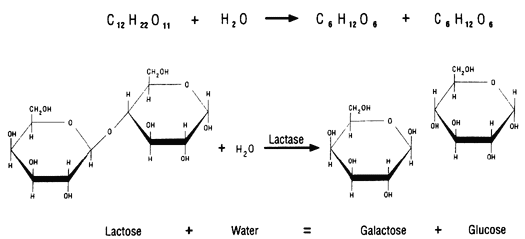
 

Sucrose Lactose

(Glucose + Fructose) (Galactose + Glucose)

Lactase is an enzyme that breaks lactose down into galactose and glucose. Lactase can be purchased in pill form by people who are lactose intolerant. These people lack the enzyme lactase, and cannot break down the sugar lactose into its component parts. Lactase is specific to lactose sugar and will not break down other disaccharides.

C12H22O11 + H2O → C6H12O6 + C6H12O6



Lactose + Water → Galactose + Glucose

In this lab, you will see lactase break lactose down into galactose and glucose by testing for the presence of glucose with glucose test strips. You will also observe what happens when lactase is added to sucrose and what happens if previously boiled lactase is added to lactose.

**PreLab Questions:**

1. What type of sugar is found in milk?
2. What two monosaccharides make up this sugar?
3. What type of biomolecule is lactase?
4. What is the difference between lactase and lactose?
5. What determines whether someone can digest lactose?

*Procedure Questions: Read the lab procedure and introduction to answer the questions below.*

1. What enzyme is being tested in this lab? What substrate does this enzyme work on?
2. What reaction is being tested?
3. How will the presence of glucose be tested?
4. If a sample tests positive for glucose, what can be assumed about the enzyme activity?

**Materials**

* Droppers
* Glucose test strips
* Lactase enzyme solution
* Lactase solution - boiled
* Lactase solution - pH 11 (basic)
* Microwell plate
* Milk
* Sucrose solution
* White paper towel

**Procedure:** Assume that each well represents a person.

1. Put the microwell plate on a white paper. Label the well plate A, B, C, D, E, and F by writing on the paper towel.
2. In well A add 10 drops of milk and 5 drops of water. This represents a person who is lactose intolerant.
3. In well B add 10 drops of milk and 5 drops of lactase enzyme solution. This represents a person who has the lactase enzyme and can digest milk.
4. In well C add 10 drops of milk and 5 drops of boiled lactase enzyme solution. This represents a person who has the lactase enzyme, but boiling the enzyme has caused denaturation.
5. In well D add 10 drops of milk and 5 drops of basic (pH 11) lactase enzyme solution. This represents a person who has the lactase enzyme, but changing the pH of the enzyme has caused denaturation.
6. In well E add 10 drops of sucrose solution and 5 drops of lactase enzyme solution. This represents a person who has the lactase enzyme, but chooses to avoid consuming dairy products.
7. In well F add 10 drops of glucose solution. This represents a control for the experiment.
8. Dip the blue end of a glucose test strip into each well plate. Leave for a minute or so.
9. Set each glucose strip on a paper towel next to the corresponding well plate hole.
10. Wait ten minutes to read the results.
11. Record data in table. If there was glucose present mark a ‘+’ in the table. If glucose was absent, mark a ‘**―**’ in the table.

**Apparatus:**

Milk Milk Milk

**A** Water **B** Enzyme **C** Boiled enzyme

Milk Sucrose Glucose

**D** Basic enzyme **E** Enzyme **F**

**Data**

|  |  |
| --- | --- |
| **Table 1: Glucose presence in the following solutions** | |
| **Type of solution** | **Positive or Negative glucose result** |
| **A:** Milk and water |  |
| **B:** Milk and lactase enzyme solution |  |
| **C:** Milk and boiled lactase enzyme solution |  |
| **D:** Milk and basic (pH 11) lactase enzyme solution |  |
| **E:** Sucrose solution and lactase enzyme solution |  |
| **F:** Glucose solution |  |

**Analysis & Conclusion**

1. *Diagram* and *describe* the lactose and lactase reaction. *Label* the reactants and products.   
   You may use simple shapes for the drawings of the molecules (see pages 43 and 44 of this lab).
2. Did the enzyme break down sucrose? Why or why not?
3. Why did the enzyme react to lactose but not to sucrose?
4. What happened when the enzyme was boiled?
5. What was the result of mixing the boiled enzyme with lactose? Explain why this happened.
6. Write a concluding paragraph about this experiment.   
   - Start by restating the purpose of the lab in past tense.   
   - Then name and describe the function of the enzyme explored in this investigation.   
   - What did the results indicate about conditions necessary for proper enzyme function?   
   - What did you learn about enzymes by doing this lab?

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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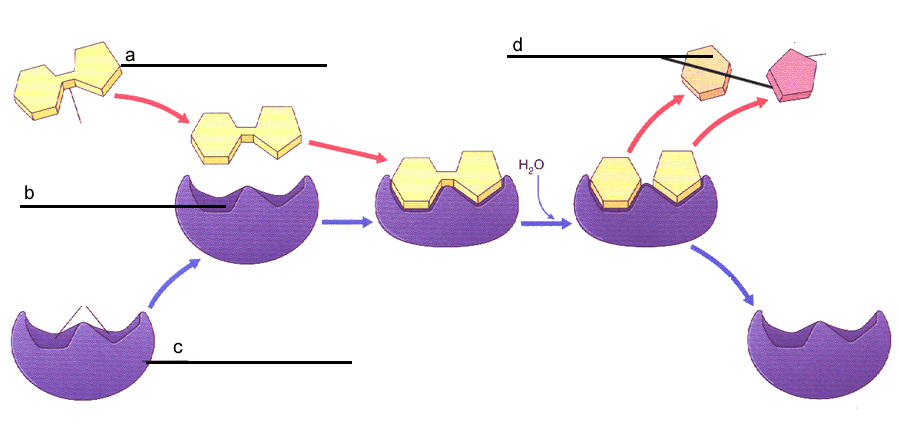
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Biology Name: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

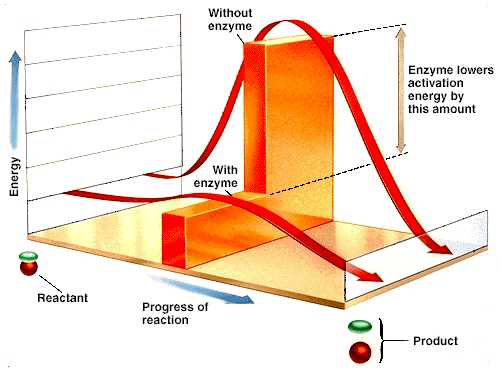
Catalyst: Enzymes Period: \_\_\_\_ Date: \_\_\_/\_\_\_/\_\_\_

**Objective 2:** Explain how enzymes act as catalysts for biological reactions.

1. Label the diagram below using the following words:
   1. Active Site
   2. Enzyme
   3. Products
   4. Reactant



1. Answer *True* or *False* to the following statements:
   1. Enzymes only interact with one specific substrate \_\_\_\_\_\_\_\_\_\_
   2. Enzymes change shape after a reaction occurs \_\_\_\_\_\_\_\_\_\_
   3. Enzymes speed up reactions \_\_\_\_\_\_\_\_\_\_
   4. One enzyme can be used for many different types of chemical reactions \_\_\_\_\_\_\_\_\_\_
2. Circle the correct effect
   1. Raising the temperature [*increases | decreases | does not change*] the rate of reaction.
   2. Changing the pH away from normal will [*increase | decrease | not change*] the rate of reaction.
3. Label the graph below using the following words:
   1. Activation Energy
   2. Products
   3. Reactant
   4. With enzyme
   5. Without enzyme



WebQuest: Enzymes Period: \_\_\_\_\_ Date: \_\_\_/\_\_\_/\_\_\_

**Materials**

* Computer with internet access
* Website: http://lpscience.fatcow.com/jwanamaker/animations/Enzyme%20activity.html

**Purpose**

The purpose of this investigation is to \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.

**Procedure**

1. Click through each of the links on the following website: http://bit.ly/1Ov4jOX
2. Complete the Questions below

**Questions**

1. Are enzymes changed as they do their job? Explain. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
2. How many substrates do enzymes work with? Explain why. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_  
     
   Draw a picture to *show* why enzymes only work with one substrate:
3. What two things cause denaturation and change how an enzyme works?
   1. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
   2. Why do these two things cause the enzyme to stop working? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
4. How do enzymes speed up reactions? (*hint:* your answer needs to include activation energy) \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Conclusion**

1. Write at least two sentences explaining what enzymes do in your body: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
2. Write at least two sentences explaining why your body produces a fever when it is infected: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
3. Write two sentences explaining what you learned about enzymes: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

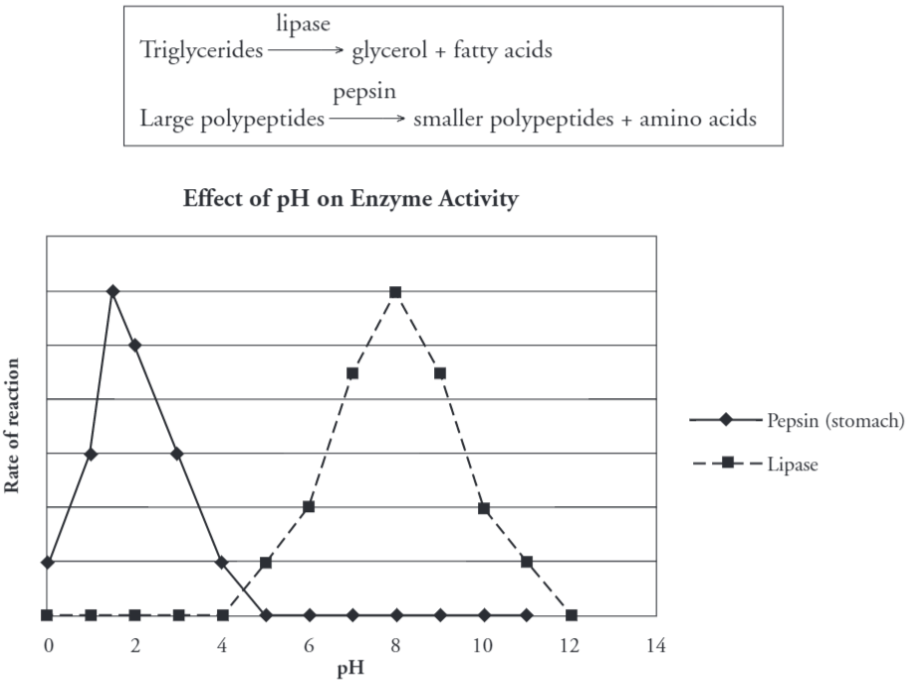
Biology Name: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

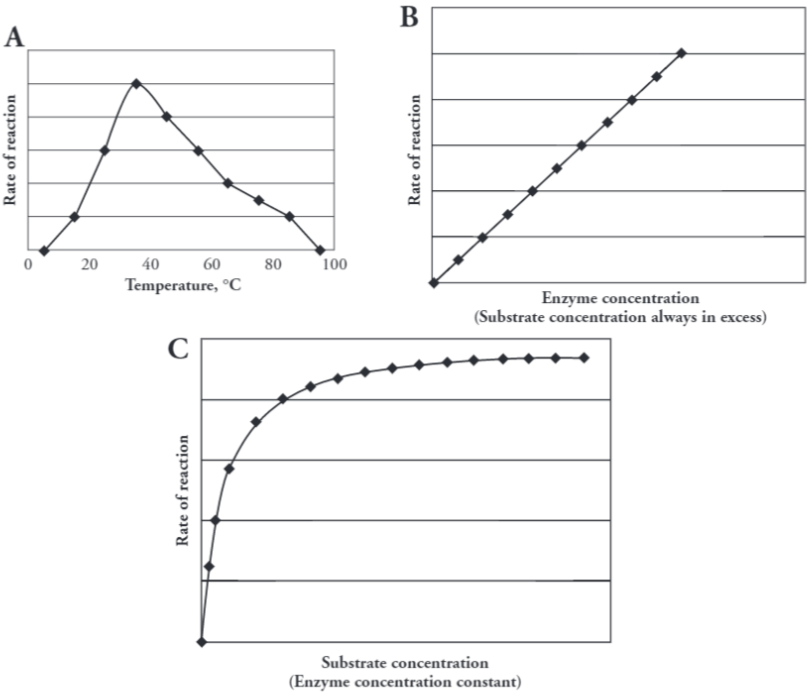
POGIL: Enzymes & Cellular Regulation Period: \_\_\_\_ Date: \_\_\_/\_\_\_/\_\_\_

**Introduction**

Digestive enzymes are protein-based biological catalysts that play important roles in our lives. They help remove stains from our shirts, turn milk into cheese, and are responsible for turning our dinner into useable fuel for our bodies. Enzymes, however, do not work well universally. Some are meant to work at high temperatures, others at low temperatures. They may work best in acidic conditions or neutral conditions. In this activity, we will look at the optimal conditions for two different enzymes. The digestive enzyme lipase is made in the pancreas and breaks down lipids in the small intestine, while pepsin breaks down proteins in the stomach.

**Model 1 – Two Digestive Enzymes**



1. Name the two enzymes illustrated in Model 1 above:
   1. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
   2. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
2. Consider the information in the Introduction section above and in Model 1 about these proteins.
   1. In which body organ is pepsin active? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
   2. In which body organ is pancreatic lipase active? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
3. For each enzyme in Model 1, circle the pH that best represents the environment in which the enzyme is *most* active:
   1. Pepsin 1.5 8.0 10.4
   2. Lipase 1.5 8.0 10.4
4. Compare the rate of the pepsin-catalyzed reaction at pH 1.5 with the rate of the lipase-catalyzed reaction at pH 1.5.   
   \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
5. Compare the rate of the pepsin-catalyzed reaction at pH 8.0 with the rate of the lipase-catalyzed reaction at pH 8.0.  
   \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
6. Using your knowledge of protein structure, explain in detail the effect of exposing an enzyme to a pH outside of its optimal range. Include the effect on both enzyme structure and function.  
   \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
7. At what pH values is lipase likely to be denatured? Justify your answer.   
   \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
8. At what pH values is pepsin likely to be denatured? Justify your answer.  
   \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
9. In addition to being produced in the pancreas, lipase is also produced in the stomach. Is the structures of pancreatic lipase the same as gastric (produced in the stomach) lipase? Justify your reasoning.   
   \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
10. Add a line to the graph in Model 1 that shows a prediction for gastric lipase activity.
11. Antacids work by neutralizing acids, bringing the pH of the stomach to a range of 6-7. What is the effect of taking an antacid on a person’s ability to digest proteins?  
    \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_  
      
    **Model 2 – Amylase Rate of Reaction**
12. Amylase is an enzyme that catalyzes the digestion of carbohydrates. The graphs in Model 2 provide data on several factors that affect the function of amylase in the body.
    1. The relationship of which two variables is illustrated in Graph A of Model 2?  
       \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
    2. The relationship of which two variables is illustrated in Graph B of Model 2?  
       \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
    3. The relationship of which two variables is illustrated in Graph C of Model 2?  
       \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
13. Refer to Model 2 as you answer the following questions:
    1. What is the optimum temperature for amylase to function correctly?  
       \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
    2. What is the biological significance of the temperature at which the amylase-catalyzed reaction is fastest?   
       \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
14. Predict what causes a decrease in enzyme activity at temperatures above 37°C.  
    \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
15. A young child runs a fever of 40°C for 24 hours. Explain what effect this may have on his/her digestion.  
    \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
16. Consider the data in Graph B of Model 2.
    1. Describe the relationship between enzyme concentration and reaction rate.   
       \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
    2. Propose an explanation for this relationship.   
       \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
17. Consider the data in Graph C of Model 2.
    1. What is the relationship between substrate concentration and the reaction rate?   
       \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
    2. Propose an explanation for why a maximum reaction rate is reached in Graph C.   
       \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
18. As a group, develop an analogy for the function of an enzyme that will explain the concentration Graphs in Model 2 (Graphs B and C).   
    \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
19. Would the reaction rate on Graph B of Model 2 ever reach a maximum level? Justify your answer.   
    \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
20. Thermophilic (heat-loving) bacteria, such as *Thermus aquaticus*, live in hot springs where the temperature is greater than 70°C. Draw a graph similar to Graph A in Model 2 representing the optimal temperature of *Thermus aquaticus*.

1. DNA polymerase (the enzyme responsible for adding new DNA nucleotides during DNA replication) from *Thermus aquaticus* (*Taq*) is used in PCR (polymerase chain reaction). PCR is a technique where millions of copies of DNA can be made from one original copy. In this method, the target DNA molecules is subjected to temperatures over 95°C to make the double-stranded DNA separate. The temperature is then lowered slightly to allow primers to anneal before the *Taq* polymerase catalyzes the reactions to incorporate new nucleotides into the complementary strands. The cycle is then repeated over and over until there are millions of copies of the target DNA.
   1. Predict why this bacterial polymerase is used instead of human polymerase.   
      \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
   2. What would happen if you used a human polymerase in a series of PCR reactions?  
      \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
2. The rate of an enzyme-catalyzed reaction can also be affected by the presence of other molecules that can bind to the enzyme, thus changing its shape. In some reactions, a coenzyme is necessary. This molecule binds to a protein strand of the enzyme, changing its shape so that it is ready to receive the substrate molecule. Without the coenzyme, the enzyme would not be able to attach to the substrate. Other molecules can reduce the rate of reaction for enzymes by binding to the protein and either blocking the spot where the substrate will bind (the active site) or by making the enzyme’s shape incompatible with the substrate. These molecules are called inhibitors.
   1. Sketch a graph that shows the relationship between the rate of an enzyme-catalyzed reaction and the concentration of coenzyme necessary for the enzyme to function properly.
   2. Add a line to Graph C of Model 2 that shows the rate of an enzyme-catalyzed reaction in the presence of inhibitor molecules.